GEOLOGIC NOTES

DIVISION OF GEOLOGY
STATE DEVELOPMENT BOARD
COLUMBIA, S. C.

MAY - AUGUST 1964

Volume 8 Number 3 & 4

GEOLOGIC NOTES

Volume 8 May - August 1964 Numbers 3 & 4

CONTENTS

DUPLIN FORMATION (LATE MIOCENE) AT THE MULDROW PLACE SUMTER COUNTY, SOUTH CAROLINA

By

Jules R. Du Bar 1/ and James F. Howard 2/

ABSTRACT

An unsuccessful search was made by the authors for exposures of fossiliferous Duplin Formation (Late Miocene) in the vicinity of the Muldrow Place, Sumter County, South Carolina. The section described by Sloan (1908, page 308) is clearly based on samples from a deep well. Material studied by Gardner and Aldrich (1919) apparently came from small marl pits that are now slumped and overgrown.

A power auger drill hole at the old Muldrow house encountered 20 feet of fossiliferous Duplin Formation. A large and varied fauna is present. It is concluded that the fossiliferous part of the Duplin Formation here was deposited on the shallow shelf in water of normal salinity and with a temperature range similar to that found off the coast of Charleston, South Carolina, today.

INTRODUCTION

The classic locality for the Duplin Formation (Late Miocene) in South Carolina is in the vicinity of the old Muldrow Estate, as reported by Sloan (1908, p. 308), Gardner and Aldrich (1919), and Cooke (1936, p. 121). Approximately 250 molluscan species were recorded from the locality by Gardner and Aldrich.

The old Muldrow Estate is located in the NW 1/4 of the Mayesville 15' quadrangle in Sumter County, South Carolina, about 1.2 miles S. 43°E. of Scotsville at latitude 33°56'40" North, longitude 80°09'10" West (Fig. 1). Gardner and Aldrich did not give the exact source of their collections, stating merely that, "The material is a blue clay marl twelve feet thick, exposed on some small streams." According to Druid Wilson of the U. S. National Museum (written communication, March 24, 1964) the collections studied by Gardner and Aldrich came, at least in part, from those made on the Muldrow Estate by Sloan and Burns in 1904. Wilson stated that the U. S. Geological Survey catalogue data is, "On a little creek on the north side of Black River on lands of Colonel J. R. Muldrow, 5 miles south of Mayesville, Sumter County -----." Wilson also noted that there was at one time a large collection from the Muldrow Estate at Johns Hopkins University, to which Gardner and Aldrich probably had access.

1/ Department of Geology, Duke University, Durham, North Carolina
2/ Department of Geology, Indiana University, Bloomington, Indiana

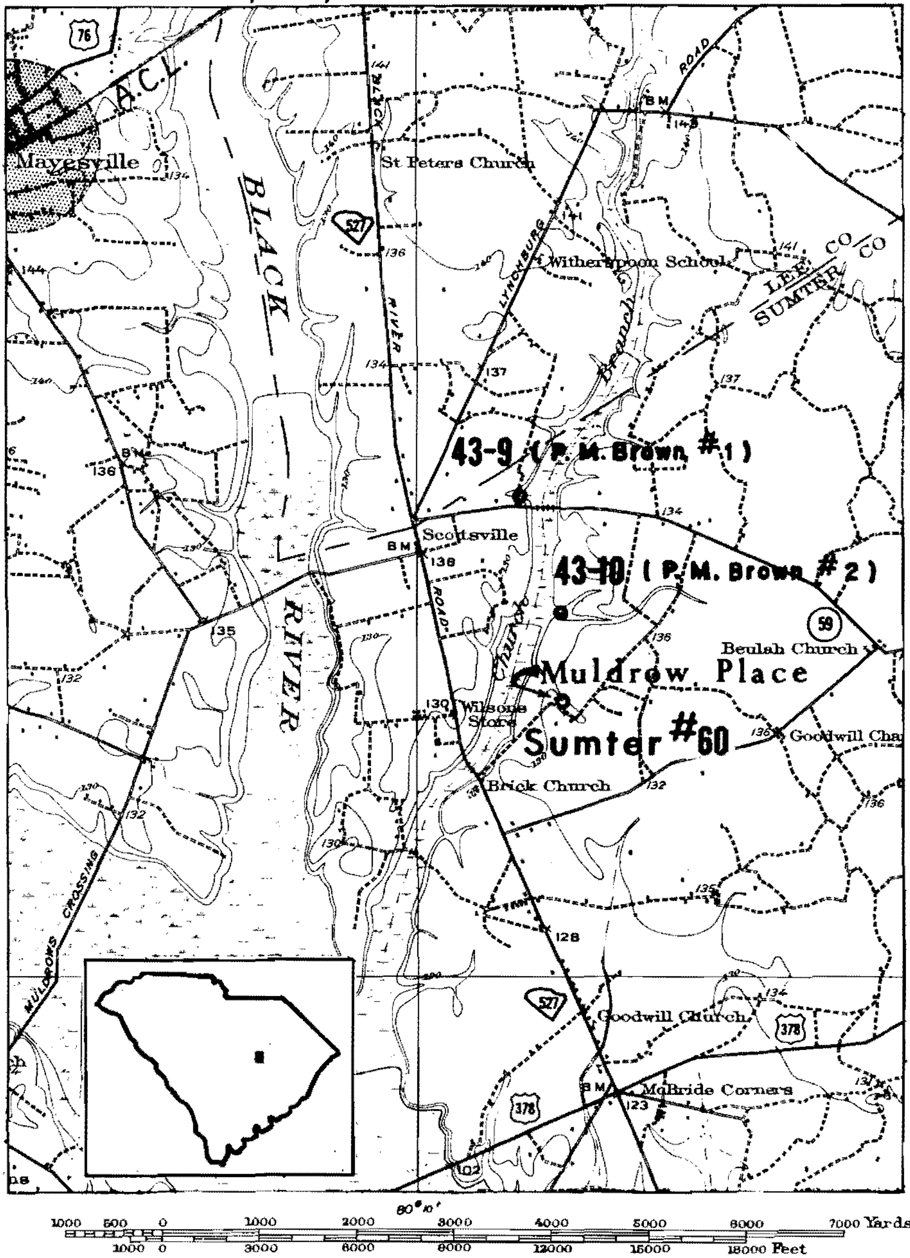

Mayesville
A.C.L.
BLACK
RIVER
St Peters Church
Witherspoon School
LYNCHBURG
ROAD
LEE CO
SUMTER CO
Branch
43-9 (P. M. Brown #1)
43-10 (P. M. Brown #2)
Scottsville
Muldrow Place
Sumter #60
Beulah Church
Goodwill Church
Wilsons Store
Brick Church
Goodwill Church
McBride Corners
MULDROWS CROSSING
1000 500 0 1000 2000 3000 4000 5000 6000 7000 Yards
1000 0 3000 6000 9000 12000 15000 18000 Feet

Fig. 1.

Cooke (1936, p. 121) stated that in 1917 the only Duplin exposures on the Muldrow Estate were in a few shallow pits in a drain leading into Church Branch. Cooke described the source bed material as a marl consisting of shells in fine clear quartz sand.

Sloan (1908, p. 308) described the following section from the Muldrow Estate:

Sands and Loams (Pleistocene ?)----------------	12.0'
Marl, consisting of loose shells in a blue clay-marl matrix (Duplin Formation)---------------	12.0'
Blue sticky material; seam of black lignitic matter-	66.0'
Dark sticky material; fossil cypress wood--------	20.0'
Dark sticky material; one foot seams of hard flint (Black Mingo and/or Black Creek formation)----	73.0'
Total	183.0'

The section described by Sloan is clearly based on samples from a water well. He gives the location as being on the edge of a swamp, but a deep artesian well drilled immediately behind the Muldrow house in the 1800's is probably the well to which Sloan refers. Sloan's stated collar elevation of 134' fits this Muldrow House well perfectly.

An attempt by the senior author to locate outcrops of the Duplin Formation on the Muldrow Estate in 1959 met with no success. In 1963 W. O. Hatchell, employed by the South Carolina Division of Geology, searched the Muldrow Estate and adjacent areas for a fossiliferous Duplin exposure but could find nothing more than a weakly calcareous sandy clay which could have contained shells that had been leached out.

Joe Fanning, W. B. Abbott and F. L. Greene, Soil Conservation Service soils scientists who have worked in eastern Sumter County, reported verbally in 1964 that no fossiliferous outcrops were known to them anywhere near the Muldrow locality. Further inquiry among tenants farming the Muldrow property also indicated that there is no knowledge of fossiliferous outcrops in the Muldrow area today.

In February 1964 the senior author and Henry S. Johnson, Jr., State Geologist of South Carolina, made a search of the creeks, ditches, and ponds in the vicinity of the Muldrow Estate. Scattered fragments of Miocene shells were found in fields between Muldrow House and the nearby swamp but no fossiliferous units of the Duplin Formation were found in place. That fossiliferous outcrops are not present in the area is easily accounted for by the flat terrain, deep soil profile, great amount of slump, and heavy undergrowth. The assemblage reported on by Gardner and Aldrich (1919) was more diversified and contained larger specimens than one could readily attribute to typical well cutting samples. Still, the authors have not determined whether any of the Gardner-Aldrich collection came from natural outcrops. Sloan (1908, p. 308) clearly described his section from well samples. He describes a 183 foot section underlain by a water-bearing unit with a hydrostatic head 21 ft. above ground surface. Today there is no outcrop approaching 180 feet in thickness in the vicinity of the Muldrow Estate, and it even seems unlikely that a 24 foot section exposing 12 feet of Pleistocene(?) sands and loams and 12 feet of Duplin marl was ever exposed in the area.

P. M. Brown of the U. S. Geological Survey supplied directions to two occurrences of fossiliferous material near the Muldrow Place. In 1954 he found microfauna in a gray sandy clay from the bottom of a drainage ditch (Fig. 1, Loc. 43-9) and macro- and micro-fossils in blue-gray sandy clay from the bottom of two small, abandoned marl pits (Fig. 1, Loc. 43-10). When these two localities were visited by Henry S. Johnson, Jr. in May 1964 they were both found to be silted and slumped over so that no fossils were observed in place. Sparse shells were present on the spoil pile of the larger of the pits at Loc. 43-10, however, and it seems likely that this marl pit or others like it in the area may have been the source of the Gardner-Aldrich collections.

To summarize, the exact source of the Gardner-Aldrich material cannot be determined. Natural outcrops exposing fossiliferous material in the vicinity of the Muldrow Place probably never existed, and the section described by Sloan is certainly derived from a well. It seems probable that most if not all of the Gardner-Aldrich material was derived from marl pits near the Muldrow House and Brick Church, but macrofossils are no longer readily available in any of these pits.

STRATIGRAPHY

In an effort to determine more precisely the biostratigraphic relations, thickness, and nature of the Duplin Formation on the Muldrow Estate a hole was drilled in July 1963 with the mobile power auger of the South Carolina Division of Geology just behind the old Muldrow house. The description of the section encountered in this drill hole is given below (Table 1).

Table 1. -- Log of Drill Hole Sumter #60

<u>Location:</u> NW 1/4 Mayesville 15' quadrangle, Sumter County, South Carolina, 50 feet behind old Col. Muldrow Plantation house; 1.2 miles S. 43° E. of Scottsville; 0.7 mile N. 44° E. of Brick Church.
<u>Collar Elevation:</u> 129' (estimated from contours)
<u>Total Depth:</u> 50'
<u>Drilled by:</u> Division of Geology, South Carolina State Development Board
<u>Date:</u> July 2, 1963
<u>Logged by:</u> H. S. Johnson, Jr. and James F. Howard; description supplemented by J. R. Du Bar

Unit	Description	Thickness in feet
Pleistocene.		
5.	Clay, sandy, plastic, grayish-orange; no fossils observed...	5
4.	Sand, very slightly argillaceous; 1-2% black phosphate(?); quartz predominant; grains moderately pitted and frosted, subangular (0. 3— 0. 6), fine to very fine, slightly consolidated, well sorted; grayish-orange (10YR 7/4); no fossils observed...	5
3.	Sand, very slightly argillaceous; 1-2% phosphate(?); quartz grains moderately pitted and frosted, subangular (0. 3— 0. 5), medium, slightly consolidated, moderately well-sorted; grayish-orange (10YR 7/4); no fossils observed..	12
Miocene.		
Duplin Formation.		
2.	Sand, silty, argillaceous, quartz, very fine to fine, slightly pitted and frosted, subangular to subrounded (0. 4— 0. 7), fair sorting, slightly consolidated, light olive-gray (5Y 6/1) (dry); macro- and micro-fossils abundant and well preserved...	20
Cretaceous ?		
Black Creek Formation ?		
1.	Silt and sand, extremely fine-grained, very argillaceous, micaceous, non-calcareous, blue-gray to black; no fossils observed...	8

The 10 ft. difference in thickness of the uppermost unfossiliferous sediments in Sumter #60 and in Sloan's section (1908, p. 308) is not readily explainable, particularly since the two holes are less than 100 feet apart. The difference may be due to the channeling nature of the fluvial sands overlying the Duplin, variations in thickness of the Duplin shell bed facies, inaccuracies in Sloan's information, or combinations of the three.

PALEONTOLOGY

The invertebrate fauna from auger hole Sumter #60 is large and varied and well preserved. It consists primarily of mollusks, foraminifers, and ostracodes, but also contains a few corals, bryozoans, barnacles, and echinoids. Approximately 32 species of pelecypods (Table 2), 30 species of gastropods (Table 2), 25 species of foraminifers (Table 3), and 16 species of ostracodes (Table 4) were identified. Nearly all of the mollusk species were reported by Gardner and Aldrich, however the foraminifers and ostracodes have not previously been studied.

Detailed paleoecologic interpretation is not practical because the sample represents a composite of a 20 foot thick section and because the larger species either have not been retrieved or have been too badly macerated by the auger to allow accurate identification.

There seems little doubt that most of the species lived in the open ocean on the shallow shelf in water 20 to 70' deep. Very few species in the samples studied suggest an enclosed, brackish water environment, although a few of the mollusk species listed by Gardner and Aldrich (1919) commonly live in such an environment today. Several of the drill hole species are today most characteristic of the intermediate shelf (12-35 fathoms) but occur also on the shallow shelf. Thus it seems safe to conclude that the most fossiliferous part of the section was deposited on the shallow shelf. The salinity of the shelf water was probably normal for the open ocean (34-36%), the water was well oxygenated, turbulent at times, relatively clear, and the temperature range was probably close to that found off the coast of Charleston, South Carolina, today.

Table 2. Check list of macrofauna from the Duplin Formation Muldrow Place, Sumter County, South Carolina

PELECYPODA

	Relative Abundance
Anadara lienosa Say?	R
Anadara transversa (Say)	R
Cardita granulata (Say)	C
Cardita perplana (Conrad)	R
Cardita tridentata (Say)	R
Caryocorbula barrattiana (C. B. Adams)	R
Caryocorbula nucleata Dall	C
Chama gardnerae Olsson & Harbison	R
Chione cribraria (Conrad)	R
Chione latilirata Conrad	R
Chlamys eboreus (Conrad)?	R
Codakia sp.	R
Crassatellites lunulata Conrad	C
Diplodonta sp.	R
Eucrassatella sp.	R
Gemma magna Dall	C
Glycymeris subovata Say?	R
Gouldia metastriata (Conrad)	R
Macrocallista reposta (Conrad)	R
Mulinia congesta Conrad	VA
Noetia limula Conrad?	R
Nucula proxima Say	R
Nuculana acuta Conrad	C
Nuculana trochilia Dall	R
Phacoides cribrarius Say	R
Phacoides multilineatus (Tuomey & Holmes)	VA
Phacoides radians (Conrad)	R
Phacoides trisulcatus Conrad	R
Phacoides tuomeyi Dall	R
Plicatula marginata Say	C
Tellina dupliniana Dall?	C
Transenella carolinensis Dall	R

GASTROPODA

Balcis magnoliana (Gardner & Aldrich)	R
Caecum cooperi S. Smith	R
Caecum flemingi Gardner & Aldrich	R
Clathrodrillia tuberculata (Emmons)	R
Crepidula fornicata Say	R
Crucibulum auriculum (Gmelin)	R
Diodora nucula Dall	R
"Drillia" sp. A	R
"Drillia" sp. B	R
Kurtziella eritima Bush	R
Kurtziella stellata Stearns	R
Lemintina granifera Say	R
Liotia gemma Tuomey & Holmes	R
Marginella sp. cf. M. aureocincta Stearns	R
Mitrella communis Gardner & Aldrich	R
Nassarius consensus Ravenel	R
Oliva sayana Lamarck	R
Olivella mutica (Say)	VA
Persicula minuta Pfeiffer	C
Petaloconchus sculpturatus H. C. Lea	R
Prunum contractum	C
Retusa canaliculata Say	C
Retusa myrmecoon Dall	R
Seila clavatulus (H. C. Lea)	R
Tectonatica pusilla Say	C
Terebra dislocata Say	R
Trophon lepidota (Dall)	R
Turbonilla sp.	R
Turritella duplinensis Gardner & Aldrich?	R
Turritella sp. indet.	R

SCAPHOPODA

Dentalium carolinense Conrad	R

ANTHOZOA

Septastrea sp.	R

BRYOZOA

Discoporella sp.	R

ARTHROPODA

Balanus sp.	R

ECHINOIDEA

Regularia spines	R

CHORDATA

Sharks teeth	R

VA = more than 40, A = 20-40, C = 5-20, R = 1-5.

Table 3. Check list of foraminifera from the Duplin Formation, Muldrow Place, Sumter County, South Carolina

Species	Relative Abundance
Ammonia sobrinus (Shupack)	A
Amphistegina floridana Cushman and Ponton	C
Angulogerina occidentalis Cushman	R
Bolivina pulchella primitiva Cushman	R
Buccella anderseni McLean	A
Buccella sp. cf. B. anderseni McLean	C
Bulimina marginospinata Cushman and Parker	R
Cibicides floridanus (Cushman)	A
Cibicides sublobus (Cushman)	C
Elphidium advenum (Cushman)	R
Elphidium discoidale (d'Orbigny)?	R
? Elphidium ellisi Weiss	R
Elphidium fimbriatulum (Cushman)	R
Elphidium gunteri Cole	R
Elphidium johnsonae McLean	C
Elphidium poeyanum (d'Orbigny)	C
Elphidium sp. (Juvenile form)	R
Globigerina sp. cf. G. eggeri Rhumbler	R
Globulina inaequalis caribea d'Orbigny	R
Guttulina costatula (Galloway and Wissler)	R
Hanzawaia concentrica (Cushman)	VA
Neoconorbina terquemi Rzehak	C
Planispirrilina orbicularis (Bagg)	R
Reussella spinulosa (Reuss)	C
Textularia gramen (d'Orbigny)	R

VA = 20 or more; A = 10-20; C = 5-10; R = 1-5

Table 4. Check list of ostracoda from the Duplin Formation, Muldrow Place, Sumter County, South Carolina

Species	Relative Abundance
Acutocythereis multipunctata Edwards	C
Aurila conradi (Howe and McGuirt)	VA
Carinocythereis rugipunctata (Ulrich and Bassler)	C
Cytherura elongata Edwards	R
Cytherura reticulata Edwards	R
Cytherura wardensis Howe and Brown	R
Haplocytheridea waltonensis Stephenson	R
Loxoconcha reticularis Edwards	C
Murrayina howei Puri	C
Neocytherideis ashermani (Ulrich and Bassler)	C
Orionina vaughani (Ulrich and Bassler)	R
Paracytheridea sp. cf. P. altila Edwards	R
Paracytheridea rugosa Edwards	R
? Paracyprideis sp.	R
Paradoxostoma elongata Puri	C
? Xestoleberis ventrostriata Swain	R

VA = more than 10; A = 5-10; C = 2-5; R = less than 2.

SUMMARY AND CONCLUSIONS

Attempts to relocate the exact source of South Carolina Miocene fossils studied by Gardner and Aldrich (1919) were not entirely successful, but it seems very likely that they came from small marl pits within about a mile of the old Col. Muldrow house, Sumter County, and possibly in part from a deep well drilled at the house in the 1800's. Sloan's (1908, p. 308) original description of the Duplin Formation at the Muldrow locality was clearly based on this well. There are no natural exposures of fossiliferous Duplin in the area today.

A power auger hole drilled by the South Carolina Division of Geology at the Muldrow house encountered a 20 foot thickness of fossiliferous Duplin Formation. Abundant invertebrate fauna from this hole compare closely with the 250 molluscan species recorded by Gardner and Aldrich (1919).

Paleoecologic interpretation indicates the Duplin in the vicinity of the Muldrow Estate was deposited in the open ocean on the shallow shelf in water 20 to 70 feet deep. Salinity was probably normal for the open ocean, the water was clear and well oxygenated, and the temperature was probably close to that off Charleston, South Carolina, today.

ACKNOWLEDGMENTS

The project was supported by funds from a National Science Foundation Grant to the senior author and also by the Division of Geology, South Carolina State Development Board. The Division of Geology supplied the mobile auger with which the hole was drilled and the actual drilling was done by Henry S. Johnson, Jr., State Geologist,and the junior author. The senior author was aided in e field by James R. Solliday of the University of Houston in 1959, by Henry S. Johnson, Jr. in 1964, and by W. O. Hatchell of the South Carolina Div sion of Geology, and by Hobart W. C. Furbunch of Myrtle Beach, South Carolina, in 1963.

Information regarding present location of molluscan collections from the Muldrow Estate and their original source was supplied by Druid Wilson of the U. S. National Museum.

Directions to other fossil localities near the Muldrow Estate were provided by P. M. Brown, U. S. Geological Survey.

REFERENCES

Cooke, C. W., 1936, Geology of the Coastal Plain of South Carolina: U. S. Geol. Survey Bull. 867, 196 p.

Gardner, Julia A. and Aldrich, T. A., 1919, Mollusca from the upper Miocene of South Carolina with descriptions of new species: Proc. Acad. Nat. Sciences, Phila., v. LXXI, p. 17-53.

Sloan, Earle, 1908, Catalogue of the mineral localities of South Carolina; Reprinted 1958 by Division of Geology, State Development Board, South Carolina, 505 p.

PETROLOGY OF METASEDIMENTARY AND VOLCANIC ROCKS ALONG HARMON CREEK IN THE IRMO N. E. QUADRANGLE SOUTH CAROLINA

By

W. O. Hatchell[1/]

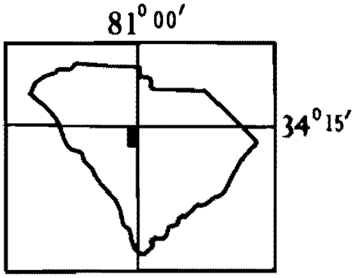
ABSTRACT

A petrologic study of approximately 2,000 feet of metamorphosed Lower Paleozoic(?) volcanic and sedimentary rocks along Harmon Creek in the Irmo N. E. quadrangle, South Carolina, has been made using the x-ray diffractometer and the petrographic microscope. Intercalated volcanic flows, tuffaceous sediments, and associated sills compose the stratigraphic section. All mineral assemblages correspond to the quartz-albite-muscovite-chlorite subfacies of the greenschist facies of regional metamorphism or the chlorite zone of Tilley. The assemblage quartz-albite-epidote-chlorite-muscovite (-calcite) is especially common among the tuffaceous sediments. The unusual association paragonite-muscovite in a calcareous phyllite and zoisite-calcite in an andesitic sill were noted. Calcic plagioclase has altered to albite, epidote, and perhaps calcite. Original clay minerals have altered to chlorite and muscovite, while original mafic constituents have altered to epidote and/or chlorite. The devitrified products of original glassy materials were reconstituted to quartz, albite, muscovite, chlorite, and ore minerals. Sedimentary textures, mineralogy, and field relationships suggest a eugeosynclinal marine environment of deposition for all of the tuffaceous rocks.

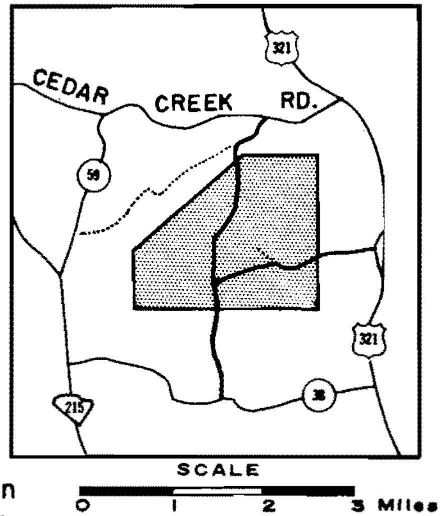
INTRODUCTION

Volcanic-sedimentary rocks of the Carolina Slate Belt cropping out along upper Harmon Creek in the Irmo N. E. quadrangle, South Carolina, (Figure 1) have been studied to determine the initial lithology and depositional environment and the subsequent effects of deformation and low-grade regional metamorphism. Previous geologic studies in the Piedmont of central South Carolina have been mainly of a reconnaissance nature with the emphasis on field work. The present study was undertaken in hope that detailed field and laboratory examination of a well-exposed but restricted section of Slate Belt volcanic-sedimentary rocks would give important basic information on the sedimentary, structural, and metamorphic history. Field and laboratory data indicate that the rocks were originally a composite series of interbedded andesitic flows, lithic graywackes, lithic-crystal graywackes, tuffaceous graywackes, and calcareous pelites deposited in a subaqueous environment. These were in turn intruded by sills of felsic and intermediate composition. This sequence dips steeply to the northwest (Figure 1). A few small drag folds indicate that

1/ Undergraduate student, University of South Carolina, 1963-64



Location of Irmo N.E. 7 1/2′ Quadrangle in South Carolina.

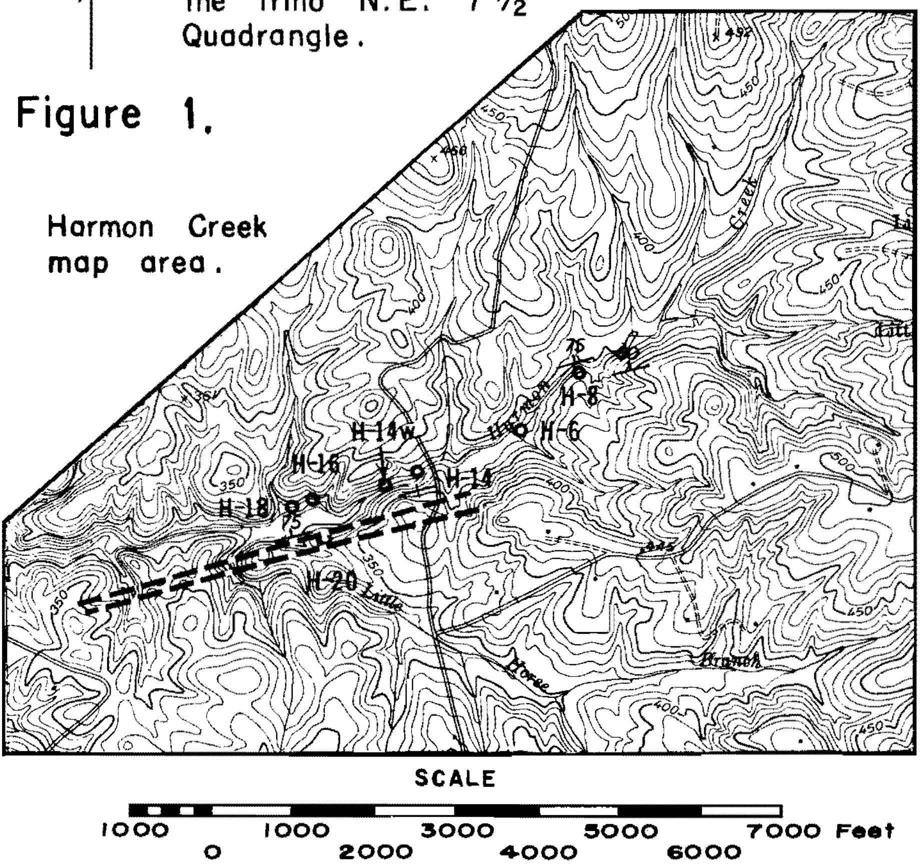


N

Location of Harmon Creek map area in the Irmo N.E. 7 1/2′ Quadrangle.

Figure 1.

Harmon Creek map area.



the strata are right-side up, presumably with an anticlinal axis or overthrust to the southeast. The entire sequence has been metamorphosed in the greenschist facies.

Field Work

Field work was done in the dry, early fall when runoff was at a minimum and when most of the unweathered rock in the stream bed was exposed, allowing sampling of fresh material. Harmon Creek was chosen in preference to other localities in the area because of generally good exposures of several varieties of volcanic and sedimentary rock. The stream flows subparallel to strike permitting detailed study of both individual rock units and of vertical and lateral lithofacies changes. Along the two-mile traverse, approximately 2,000 feet of section were observed.

Laboratory Technique

A detailed petrographic study was undertaken on all samples collected in order to determine the mineralogy and to detect any primary or metamorphic textures of genetic significance. In all, some 30 thin sections from Harmon Creek and the immediate area were studied. Plagioclase composition determinations were made by the Michel-Levy and a-normal methods. Mineral percentages were estimated visually, and some were checked for accuracy by point counting. The sodium cobaltinitrite staining technique was used on a few specimens in an attempt to detect potassic feldspar (Heinrich, 1956).

An x-ray diffractometer study was also made on all samples for the purpose of confirming the optic determinations and in order to detect mineral phases such as microcline, paragonite, and stilpnomelane which might be otherwise misidentified or overlooked in the petrographic study. A small amount of finely ground rock powder was mounted in an aluminum holder for analysis in the Phillips diffractometer. A copper tube with nickel filter was used. Instrument settings for optimum peak intensity and resolution were as follows: goniometer speed 1° 2θ per minute, chart speed 1/2 inch per minute, multiplier 5×10^{2}, and time constant 2.

REGIONAL GEOLOGY

In South Carolina, the Slate Belt outcrops along a southwest-trending zone some twenty miles in width in the eastern Piedmont Province, from Chesterfield County on the North Carolina border to Edgefield County on the Georgia border. Contrary to what the name implies, it is composed chiefly of volcanic tuffs and flows ranging in composition from mafic to felsic, interbedded with units of pelitic to arenaceous land waste, and containing a distinctive upper(?) series of rhythmically-bedded argillites.

Previous Work

Broad regional as well as local stratigraphic and structural relationships have been established. McCauley (1959, 1961), while engaged in geologic mapping of Newberry County, South Carolina, observed that rocks of the Carolina Slate Belt in southeastern Newberry County appeared to lie along the northwestern limb of a major synclinorium with higher grade Charlotte Belt metamorphic rocks to the northwest along an adjacent anticlinorium. From his field and petrographic descriptions, he concluded that rocks of the Slate Belt in Newberry County are of eugeosynclinal origin and that their most striking feature is the low grade of metamorphism which they exhibit compared to the gneisses of the Charlotte Belt. Ridgeway (1960), Bright (1962), and Paradeses (1962) have each mapped 7 1/2 minute quadrangles in the Carolina Slate Belt in the vicinity of Columbia and have established some stratigraphic relationships. In Orange County, North Carolina, Butler (1963) concluded that a series of volcanic-sedimentary clastics and interbedded flows had undergone mild regional metamorphism within the chlorite zone. Shufflebarger (1961), from a regional Piedmont study, considered the low rank Slate Belt-type rocks as infolded and/or downfaulted remnants within the Piedmont complex. He tentatively assigned to them an Ordovician age and correlated them with similiar rocks northeast and southwest of the Carolinas, namely the Little River Series of Georgia and Virgillina-Arvonia-Quantico Slates of Virginia. Similiarly, Keith and Sterrett (1931) and Kesler (1936) have suggested that the rocks of the Carolina Slate Belt, Kings Mountain Belt, and Little River Series are stratigraphic equivalents. A Paleozoic age has been substantiated for some granitic intrusives in the Carolina Piedmont from lead-alpha age determinations on zircon (Overstreet, Bell, Rose and Stern, 1961). The dates on the Piedmont granites fall broadly into three major episodes of igneous intrusion, folding, metamorphism, erosion and sedimentation. Unconformities found within the Kings Mountain Belt were correlated with those of the Slate Belt by Overstreet and Bell (1960), and it was recognized that these two lithologically and metamorphically different Piedmont belts are possible age equivalents.

MINERAL ASSEMBLAGES

The following mineral assemblages were determined for rocks along Harmon Creek:

Sedimentary Units.

Quartz-Albite-Epidote-Chlorite-Muscovite-Calcite
Quartz-Albite-Epidote-Chlorite-Muscovite
Quartz-Albite-Epidote-Chlorite
Quartz-Albite-Epidote-Muscovite
Quartz-Chlorite-Muscovite-Paragonite-Calcite

Volcanic Units.

Quartz-Albite-Zoisite-Chlorite-Muscovite-Calcite
Quartz-Albite-Chlorite-Muscovite
Albite-Epidote-Chlorite-Muscovite

ROCK UNITS

Lithic Graywacke

The lithic graywackes are characteristically a medium bluish gray color (Munsell 5B5/1), massive, and composed predominantly of unsorted lithic and quartzo-feldspathic clasts ranging up to one inch in diameter. A light gray (Munsell N6) matrix of finer-grained detritus contrasts with the clasts, imparting to the rock a distinctively coarse spotted appearance (Figure 2A). In thin section (Figure 2B), the lithic clasts are largely altered to epidote, and the quartzo-feldspathic clasts, presumably devitrified pumice lapilli, are flattened compacted blebs normally charged with ore mineral grains. Both types of clasts are embedded in a matrix of coarse epidote, subrounded and twinned albite, strained bluish gray quartz grains, and sparse flakes of chlorite. The common mineral assemblage for the lithic graywacke is quartz-albite-epidote-chlorite. One representative specimen had the following volume mineral percentages: Epidote 75, Albite 20, Quartz 3, Chlorite 2, Ore Minerals trace. Lithic graywacke locality H18 is indicated on the map of Harmon Creek area, Figure 1.

Lithic-crystal Graywacke

Rocks described as lithic-crystal graywackes are gradational from lithic graywackes to tuffaceous graywackes. The lithic fragments seldom exceed one-quarter inch in diameter. Flattened pumice lapilli(?), as previously described, comprise about one-half of the lithic clasts. A type of indistinct sedimentary compaction layering of these clasts and associated ore minerals is evident in thin section. The matrix of the lithic-crystal graywacke contains a proportionately greater percentage of quartz and feldspar detritus as compared with the lithic graywacke. Again, strained quartz, twinned albite, and epidote grains make up the matrix of the rock (Figure 2D). The volume mineral percentages are: Albite 55, Epidote 15, Quartz 15, Muscovite 10, Chlorite 5, Ore Minerals trace.

Tuffaceous Graywacke

The tuffaceous graywacke is a dense, dark greenish gray color (Munsell 5GY4/1) and is composed of poorly sorted silt and sand-sized detritus with occasional thin, flattened white blebs or clasts (pumice lapilli?). In hand specimen (Figure 2E) and outcrop, conspicuous layers one-half to two inches thick composed of silt and sand-sized particles are evident. Both the fine-grained and the coarse-grained phases are illustrated in figure 2F, G. As opposed to the lithic graywackes, a limited degree of sorting has been attained. Calcite, perhaps of sedimentary origin, is a normal constituent. In thin section (Figure 2F, G), rounded and strained blue quartz grains are relatively abundant, along with lesser amounts of angular to subrounded feldspar grains. Fine-grained flaky muscovite and chlorite occur as thin laminae and as intergranular matrix intimately associated with calcite. The volume mineral percentages are: Albite 60, Quartz 26, Muscovite 10, Chlorite 2, Epidote 1, Calcite 1, Ore Minerals trace. Tuffaceous graywacke was found at locality H14w indicated on the Harmon Creek map, Figure 1.

Calcareous Phyllite

The calcareous phyllite is a fine-grained, dark gray to black, crinkled rock with a hackly fracture. It exhibits minor foliation better than any of the other units studied, and apparently behaved incompetently during deformation. A very fine-grained assemblage of chlorite-epidote-paragonite-muscovite-calcite makes up the rock along with occasional lenticular aggregates of coarse-grained quartz and calcite which occur in discontinuous layers parallel to the s-plane foliation. The occurrence of paragonite and the absence of albite is peculiar to the calcareous phyllite. Volume mineral percentages are: White mica 43, Calcite 30, Quartz 25, Chlorite 2, Epidote trace, Ore Minerals trace. Locality H16, Figure 1, indicates the stratigraphic position of the calcareous phyllite with relation to the other Harmon Creek sediments.

Andesite Porphyry

This unit crops out at only one place on the upper course of Harmon Creek (Locality H8, Figure 1), where the upper eight feet of a flow(?) is exposed. Large euhedral phenocrysts of albite, ranging in size up to three-eighths of an inch in width and almost one-half inch in length, set in a greenish gray (Munsell 5G6/1) groundmass, lend a distinctive appearance to the andesite porphyry (Figure 3A). Under magnification and crossed nicols (Figure 3B), the rock exhibits a relict porphyritic texture with randomly oriented albite microlites surrounding large albite euhedra. Attrition or corrosion of the phenocrysts in a common phenomenon. Relict compositional zoning is vaguely distinguishable in some of the feldspars, the more calcic zones containing a higher percentage of epidote. Devitrified glassy fractions of the groundmass are apparently chloritized and speckled with occasional grains of ore. The quartz-free mineral assemblage albite-epidote-chlorite-muscovite is restricted to this unit. Volume mineral percentages are as follows: Albite 75, Epidote 15, Chlorite 6, Muscovite 4, Ore Minerals trace.

Felsic Sill

The felsic sill is a very tough massive leucocratic rock with aplitic texture in hand specimen, from two to five feet thick, cropping out along Harmon Creek at the road crossing (Locality H14, Figure 1). In thin section, (Figure 3C), the texture is xenomorphic-granular with sparse euhedral to somewhat corroded plagioclase phenocrysts set in a sugary groundmass of quartz, albite, and sparse muscovite. Several feldspars are sieved with fine-grained muscovite, and the entire rock is sericitized in part. Epidote and chlorite are present in trace amounts, the latter occurs apparently as pseudomorphs of an original mafic mineral. Minor calcite is also evident. The typical assemblage is quartz-albite-chlorite-muscovite (-epidote) (-calcite). Volume mineral percentages are: Albite 70, Quartz 15, Muscovite 10, Chlorite 3, Calcite 2.

Andesitic Sill

The andesitic sill is about 40 feet thick and traceable for over a mile along strike (Figure 1, Loc. H 20). It has suffered retrogressive metamorphism to the greenschist facies, and has a poorly-defined foliation. The color of the fresh rock is a speckled green and white. In most instances, the carbonate grains have weathered out leaving yellow to brown voids. The vermicular quartz-feldspar intergrowths, lack of bedding, and uniformly granular texture imply an intrusive origin; however, the unit could be a thick flow. The insipient s-plane foliation (Figure 3D) is particularly evident in thin section and is a result of a subparallel orientation of the chlorite flakes. Ore, possibly magnetite, is common and appears as square and rhombic grains distributed throughout the groundmass. Calcite is relatively abundant, occurring as coarse interlocking grains. The mineral assemblage is quartz-albite-zoisite-chlorite-muscovite-calcite. Volume mineral percentages are as follows: Quartz 22, Albite 22, Chlorite 22, Muscovite 22, Calcite 10, Zoisite 2, Ore Minerals trace.

Figure 2 (A) Lithic graywacke, cut slab, X 1/2. (B) Thin section, plane polarized light. Epidotized lithic clasts in fine-grained matrix of quartz, albite, chlorite and ore. X 12.

Figure 2 (C) Lithic-crystal graywacke, cut slab, X 1/2. (D) Thin section, crossed nicols. Epidotized lithic clasts, albite grains, and strained quartz detritus. X 12.

Figure 2 (E) Tuffaceous graywacke, cut slab, X 1. (F) Coarse-grained phase, (G) Finer-grained phase, crossed nicols. Albite and quartz clasts in matrix of muscovite, chlorite, minor epidote and ore. X 12.

PETROGENESIS

The meta-sedimentary units were originally composed of tuffaceous debris of andesitic composition mixed with land-derived waste. The bulk of the coarse clastic material is composed of older volcanic and/or sedimentary rock fragments along with pumic lapilli(?). Clay and carbonate minerals composed the finer-grained matrices along with grains of strained blue quartz of probable metamorphic origin and angular to subrounded feldspar phenocrysts of pyroclastic origin.

The andesite porphyry flow(?) may be somewhat more mafic than the bulk of the tuffaceous sediments because it contains no free quartz. Conversely, the thin felsic sill is unusual in that it contains only minor amounts of ferromagnesian minerals.

Tuffaceous debris is exceedingly susceptible to diagenetic alteration and initial metamorphic changes due to its chemical instability. Probably the rocks went through the initial stage of metamorphism in the zeo-

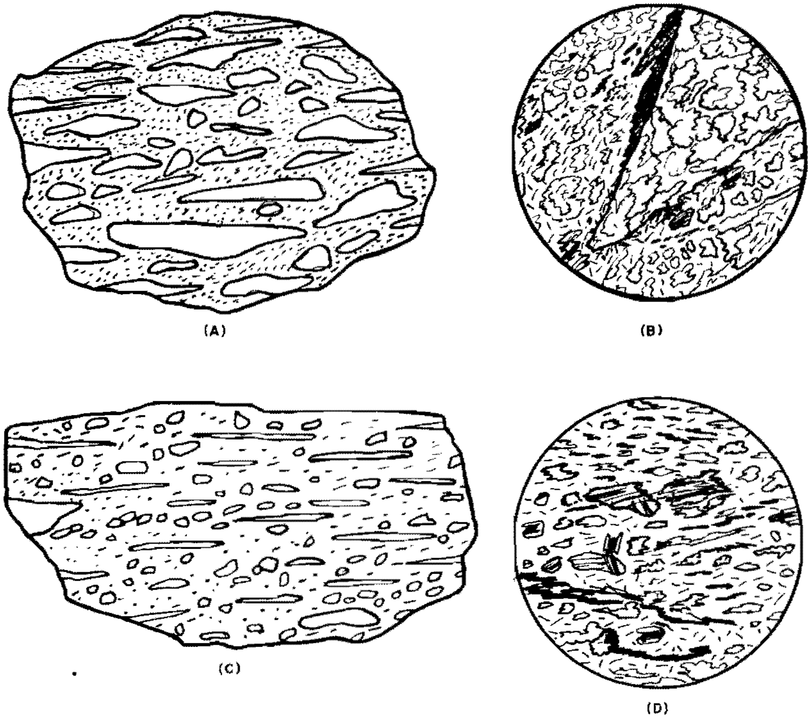
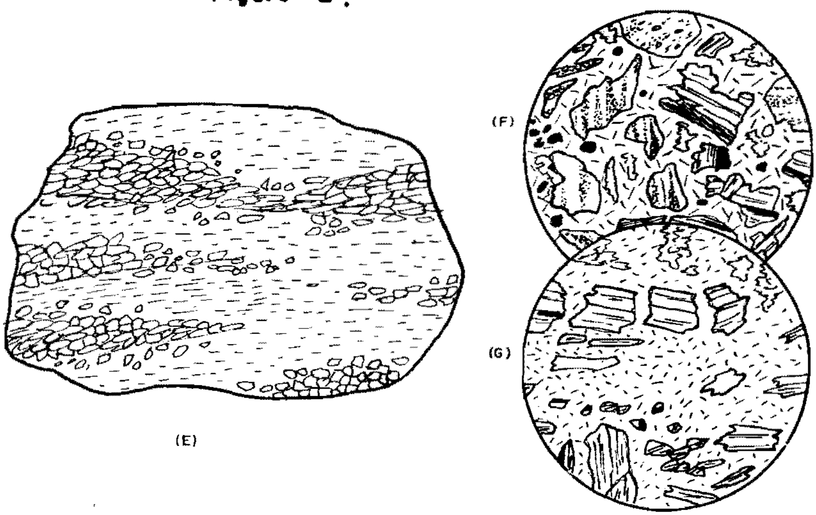


Figure 2.



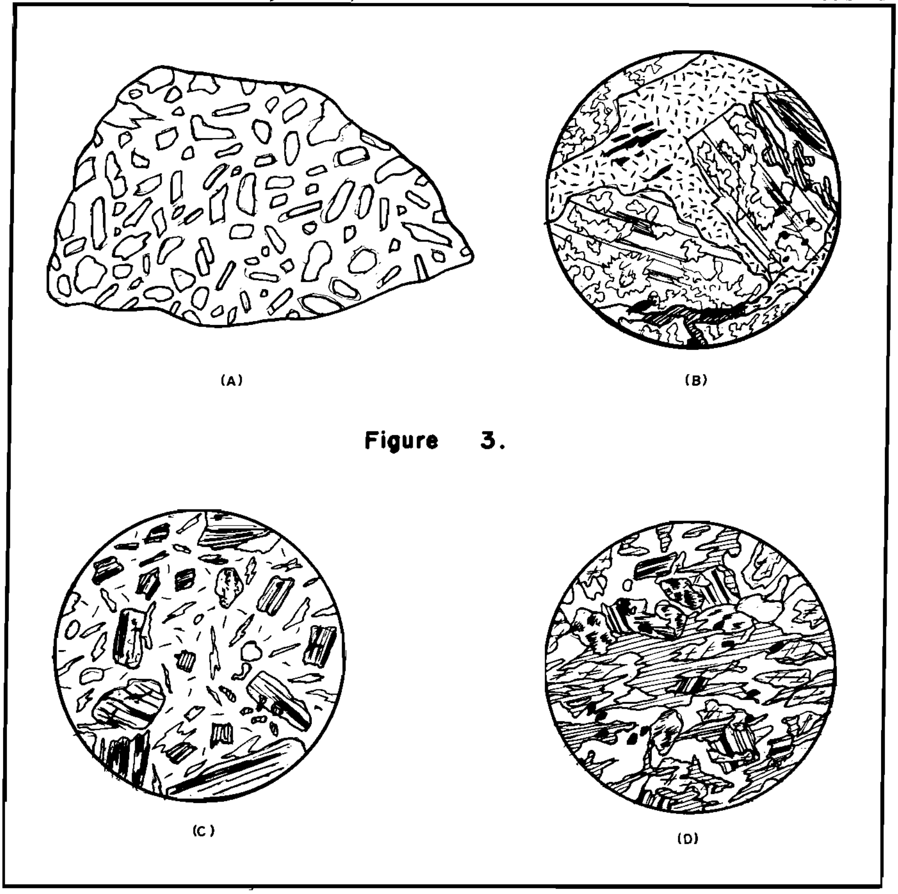


Figure 3.

Figure 3(A) Andesite porphyry, cut slab, X 1/2. (B) Thin section, crossed nicols. Albite phenocrysts replaced partially by epidote. Microlitic groundmass of albite, chlorite, and ore. Porphyritic texture. X 12.

Figure 3(C) Felsic sill. Thin section showing albite altered in part to muscovite and calcite, mafic minerals to chlorite. Xenomorphic-granular texture. Crossed nicols, X 12.

Figure 3(D) Andesitic sill. Thin section showing igneous texture. Albite, quartz, chlorite, zoisite, muscovite, and minor ore compose the rack. Crossed nicols, X 12.

lite facies as described from Jurassic strata in Oregon by Dickenson (1962). Mineral assemblages presently observed are completely stable within the greenschist facies, and no trace of lower grade assemblages were found. Original mafic components have altered to epidote and chlorite, calcic plagioclase to epidote, albite, and perhaps some calcite, and potassic feldspars and clay minerals to the white micas (muscovite and paragonite). Original quartz detritus and sedimentary carbonate appear to have suffered no alteration. The study failed to find paragonite in association with albite in agreement with the findings of Zen (1960).

In an attempt to identify and distinguish welded tuffs from non-welded tuffs or tuffaceous sediments, a few textural and field criteria were established. As has been observed by Smith (1960) and many other workers in volcanic terrane, the task of positively identifying such deposits is most difficult, especially after mild metamorphism has been superimposed as with the rocks being considered here. The Harmon Creek rocks were deposited in a volcanic environment where one might reasonably expect to find welded tuffs. However, this interpretation has been rejected for the following reasons:

1. In some of the tuff units, lithic fragments and crystals are moderately well rounded, and have apparently been transported by normal sedimentary processes.
2. Most of the tuff units originally contained some material of non-volcanic origin such as strained bluish gray quartz grains.
3. The authigenic(?) calcite in some of the units indicates subaqueous and probably marine deposition.

SUMMARY

All of the observed mineral assemblages are compatible with the chlorite zone of regional metamorphism. Original sedimentary and igneous textures have generally been preserved, permitting reasonably accurate petrogenetic interpretation. Petrographic and field data indicate that the Harmon Creek rocks are predominantly a sequence of interbedded pyroclastic sediments and lithic graywackes probably deposited in the Appalachian eugeosyncline during the early Paleozoic Era. Igneous associates are minor in proportion to the sediments and consist of an andesitic porphyry flow(?), and felsic and intermediate sills. Structurally, the entire sequence appears to be in the steeply dipping northwest limb of an anticline whose axis lies to the southeast. The common mineral assemblage developed during greenschist metamorphism is quartz-albite-chlorite-muscovite-epidote.

ACKNOWLEDGEMENTS

The study was made under the auspices of the Department of Geology at the University of South Carolina and was financed through the aid of National Science Foundation Undergraduate Research Participation Grant GE 2630. The writer wishes to express his gratitude to Dr. Donald T. Secor who advised and assisted in every phase of the study. Graduate student W. Wendell Carney kindly assisted in the preparation of slides and illustrations.

REFERENCES CITED

Bright, William E., 1962, Geology of the Irmo N. E., South Carolina, quadrangle: Thesis in partial fulfillment for the degree of Master of Science, Columbia, South Carolina, University of South Carolina Press.

Butler, James R., 1963, Rocks of the Carolina Slate Belt in Orange County, North Carolina: Southeastern Geology, vol. 4, no. 3, pp. 167-183.

Dickenson, William R., 1962, Petrology of Jurassic marine tuffs, central Oregon: Am. J. Sc., vol. 260, pp. 481-500.

Heinrich, E. William, 1956, Methods of Microscopic Study: Microscopic Petrography, chap. 1, pp. 7-8.

Keith, Arthur, and Sterrett, D. B., 1931, Description of the Gaffney and Kings Mountain quadrangles: U. S. G. S. Atlas, Folio 222, pp. 1-13.

Kesler, T. L., 1936, Granitic injection processes in the Columbia quadrangle, South Carolina: Journal of Geology, vol. 44, no. 1, pp. 32-42.

McCauley, John F., 1959, The Carolina Slate Belt and Charlotte Belt in Newberry County, South Carolina: Geol. Soc. of Am. Bull., vol. 71, p. 2021, (Abstract).

__________, 1961, Relationship between the Carolina Slate Belt and the Charlotte Belt in Newberry County, South Carolina: Geologic Notes, vol. 5, no. 5, pp. 61-65.

Overstreet, W. C., Bell, Henry III, 1960 Geologic relations inferred from Provisional Geologic Map of the Crystalline Rocks of South Carolina: U.S.G.S. Prof. Paper no. 400-B.

Overstreet, W. C., Bell, Henry III, Rose, Harry J., Jr., and Stern, Thomas W., 1961, Recent lead-alpha age determinations on zircon from the Carolina Piedmont: Geologic Notes, vol. 6, no. 5, reprint from U.S.G.S. Prof. Paper 424-B, 1961.

Paradeses, William D., 1962, Geology of the Blythewood, South Carolina, quadrangle: Thesis in partial fulfillment for the degree of Master of Science, Columbia, South Carolina, University of South Carolina Press.

Ridgeway, David C., 1960, Geology of the Blaney, South Carolina, quadrangle: Thesis in partial fulfillment for the degree of Master of Science, Columbia, South Carolina, University of South Carolina Press.

Shufflebarger, T. E., Jr., 1961, Notes on relationship of Piedmont metasedimentary rocks with emphasis on Poor Mountain-Chauga River area, Oconee County, South Carolina: Geologic Notes, v. 5, no. 3, pp. 31-33.

Smith, Robert L., 1960, Ash flows: Geol. Soc. Am. Bull., v. 71, no. 6, pp. 795-842.

Zen, E. A., 1960, Metamorphism of Lower Paleozoic rocks of the Taconic Range in Vermont: American Mineralogist, v. 45, nos. 1 & 2, pp. 129-173.